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Large Diesel Engines and Their Lubrication

THE Diesel engine is one of the outstanding factors today in marine and industrial power production. Out of an era of experimentation it has emerged as a most practical and efficient type of prime mover. For marine service, only until lately, the Diesel engine was deemed rarely adaptable to any but vessels of lighter tonnage. In shaft power rating it usually ranged considerably below 1,000 horse-power. Today, in contrast it is capable of turning up to approximately 8,000 horse-power per shaft, driving vessels up to 31,000 gross tonnage with a remarkable maneuvering flexibility. Large stationary Diesel engines, however, have not as yet been so fully developed.

Withal its efficiency and practicability, however, the Diesel engine has naturally its problems of operation. This is to be expected by reason of its relative intricacy, the fineness of its design and construction and its potential efficiency. Built by master craftsmen in the field of internal combustion engineering, it is intended for operation by master engineers. Then will its problems become negligible and its maintenance but a minor detail. Nevertheless, it is advisable to discuss these, perhaps as a matter of education to some, certainly as a matter of interest to all.

Lubrication, as in the case of any piece of high grade machinery, is the real solution to the more serious problems of Diesel engine operation, and the reduction of maintenance costs. Wear is the basic cause of trouble at sea, just as in the stationary power plant or in fact on any type of industrial machinery. Reduction

of wear is, therefore, a vital essential. Lubrication by means of high grade lubricants properly applied is the practical means whereby wear can be maintained at a minimum and engines kept in best condition for instant or continuous service.

So it is with lubrication of the larger types of Diesel engines that this article will chiefly deal.

Constructional Features

In order to best understand later remarks regarding lubrication, for the sake of refreshing our memory it is deemed well to briefly review the principles of operation involved in the Diesel, and the essential differences in construction which are of necessity involved.

The Diesel engine may be of either the four or two cycle type. It is interesting to see just what is meant by these terms. Practically speaking they involve the number of times the piston must travel from one end of the cylinder to the other in order to complete the combustion of one charge of fuel.

Perhaps it would be more exact, therefore, to refer to such engines as four-stroke cycle or two-stroke cycle respectively. Common usage, however, has abbreviated them to the terms four-cycle and two-cycle, the matter of strokes being understood as implied.

The Four-Cycle Principle

In the Diesel engine of the four-cycle type the cycle of operation includes:

1. The suction stroke, wherein the piston moves downward or away from the head of the

cylinder, to suck in a charge of air through the admission valve which is mechanically opened.

2. The compression stroke, wherein the piston travels upward or back over this path. All the valves are closed during this stroke, consequently the charge of air enclosed within the

head, the exhaust valve opening meanwhile to allow for expulsion of the exhaust gases.

The Two-Cycle Principle

In the two-cycle engine, the four essential stages of a complete cycle which the fuel must undergo in its passage through the engine, viz.: suction or admission, compression, explosion and expansion, and exhaust, take place over two strokes of the piston or during one complete revolution of the crank. As a result the number of power strokes per revolution in an engine of this type will be the same as the number of cylinders.

Essentially there is no theoretical difference between the four-cycle and two-cycle principles of power development. In the two-cycle engine but two strokes are necessary to complete a cycle. The pistons expel the exhaust gases out through the exhaust valves or ports. There-

Courtesy of McIntosh & Seymour Corporation.
Fig. 1—Side view of a 2700 B. H. P. four-cycle, single acting Diesel engine. This engine is force-feed lubricated throughout.

cylinder is compressed, the pressure rising to about 500 pounds per square inch. The temperature is thereby raised to the neighborhood of 1,000 degrees Fahr., which being above the ignition temperature of the average liquid fuel, will serve to ignite it and bring about complete combustion when the fuel is sprayed in.

3. The power stroke, wherein the piston once again travels downward or away from the cylinder head, when the fuel valve opens simultaneously to spray its charge of oil into the clearance space and combustion chamber. This fuel spray is brought about either by means of air pressure from the air reservoirs, higher than the compression pressure, as in the air injection type, or by means of a suitable pump as in the solid or airless injection type. It is interesting to note that contrary to the carburetor type of engine, there is no quick explosion such as would be produced by a spark, and therefore not the same rise in pressure, although the peak will usually be higher. The fuel simply burns to completion, over the period of ignition, the resultant pressure of the gases rising and, after injection ceases, performing work upon the piston to force it once again through its downward stroke. With the exception of the fuel valve which remains open for approximately 1-10 of the stroke, all other valves are closed.

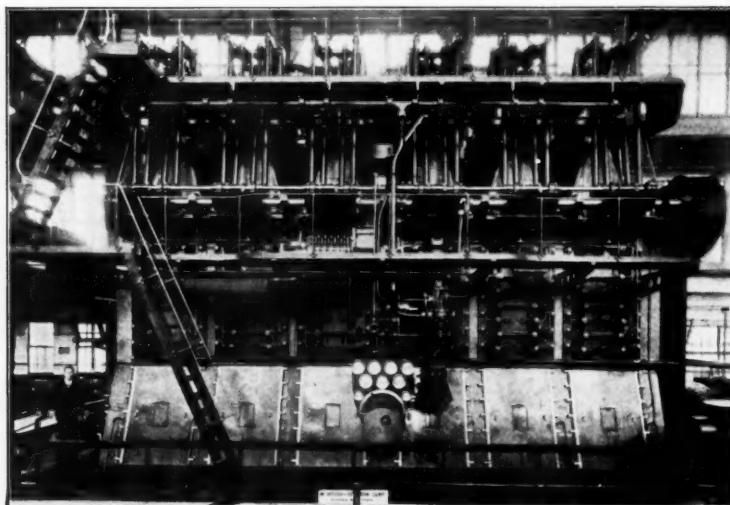
4. The exhaust stroke wherein the piston once more travels upward towards the cylinder

fore, with the completion of the exhaust stroke, fresh air is blown into the cylinders by means of a scavenging pump, thus eliminating the necessity for exhaust and suction strokes. In a two-cycle engine twice as many power strokes result in a given number of revolutions; in consequence, theoretically, twice as much power should be developed in event of each impulse being as great as its corresponding impulse in a four-cycle engine.

Within the range of power capacities required, the two-cycle type of Diesel engine has proven to be very economical from both the viewpoints of installation and operating costs. For example, it is interesting to note that the best fuel consumption ranges are getting down to the neighborhood of 0.4 pounds per brake horse-power hour, while the lubricating oil consumption is approximately one gallon per 3,000 to 4,000 horse-power hours, or even better according to some manufacturers.

Development and Economy

The principle of the original Diesel engine involved the combustion of fuels within the engine, ignition being brought about by the heat of compressed air; it was based on the four-cycle principle. In other words, four complete strokes of the piston from one end of the cylinder to the other were necessary in the attainment of a complete working cycle.



LUBRICATION

Since that time, however, the oil engine has passed through a stage of development which has proven that the four-cycle type is also adaptable to the semi-diesel engine wherein ignition is brought about by means of a hot bulb or plate, the oil being injected onto the heated surface. The full Diesel principle is more extensively employed in larger types of marine and stationary engines. Its advancement to a place of prominence in the generation of power has been decidedly marked over the past decade. For a moment it is interesting to look into the reason for this.

The Diesel engine consumes about one-third as much fuel per unit of power developed as does the average heat engine of corresponding rating. With rare exceptions, it functions independently of carburetors and other external ignition systems of this nature. Furthermore,

sure and temperature that the fuel burns as soon as admitted.

METHODS OF INJECTION AND FUEL EFFICIENCY

The quality of fuel oil may vary through a considerable range if the spray air pressure is varied to give proper atomization. The amount of adjustment in regard to compression pressure, and the details of the spray nozzle, etc., will depend upon the nature of the fuel being fired.

Methods of Injection

Fuel is injected into the Diesel engine either alone as in the solid injection type of engine, or in company with compressed air as an atomizing agent. The earlier Diesel plans called for charging of the fuel alone. Later, however, it was developed that compressed air was a decidedly effective means of atomizing the oil sufficiently to bring about instantaneous combustion. The extent to which this air should be compressed was found to depend upon the grade and viscosity of the fuel oil, the load carried by the engine and the design and construction of the atomizing equipment.

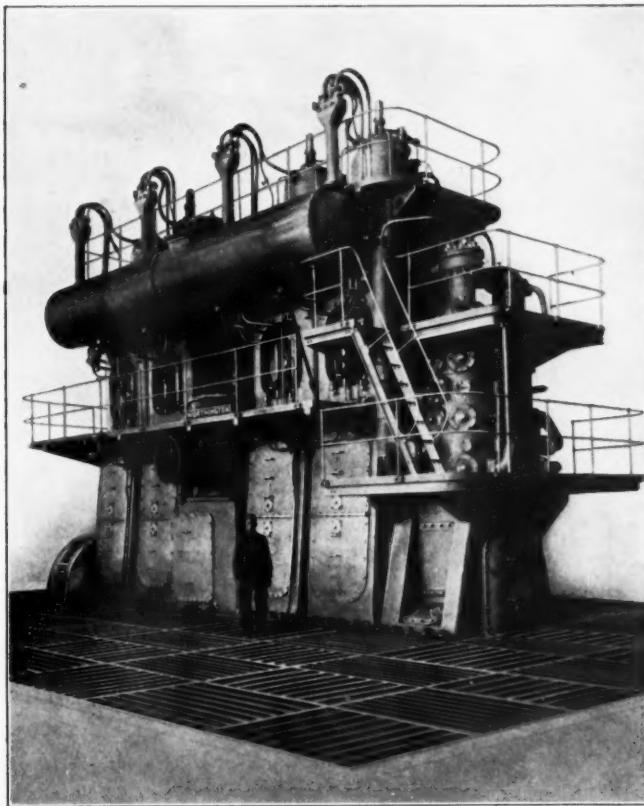
Where air injection is involved the oil in the average Diesel engine of larger size will be pumped to the fuel valves under suitable pressure, and atomized by compressed air, combustion being brought about by virtue of the hot compressed air within the combustion chamber.

In the solid injection of liquid fuel into an oil engine, one of three procedures in turn can be used. Either the oil is pumped to the fuel valves under sufficient pressure to effect vaporization, being subjected to combustion in measured quantities when the above valves are opened for admission; a separate plunger pump can be used for each cylinder, such a pump serving to meter out the requisite amount of fuel and deliver

it at the necessary pressure; or, a central pump with a distributor can be used instead.

Factors Affecting Combustion

Essentially, whatever the means by which the fuel is delivered and ignited, the purpose in



Courtesy of Worthington Pump and Machinery Corp.

Fig. 2—Side view of a two-cycle double acting Diesel engine of 2900 H. P. recently accepted by the U. S. Shipping Board. This is the largest engine of its kind to date.

the Diesel engine of today is capable of burning practically any grade of liquid fuel from kerosene to crude oils; especially is this true of the full Diesel type where fuel injection into the cylinder occurs after the upward stroke of the piston has compressed pure air to such a pres-

view is to so vaporize or atomize it and bring about such a mixture with the necessary air for combustion that it will be burned completely, with a minimum of residual matter such as carbon and ash remaining in the cylinder. To



Courtesy of Bethlehem Shipbuilding Corp'n, Ltd.

Fig. 3—Cross-sectional view of a large unit, two-cycle, single acting oil engine, through center of power cylinder and valve cage. This is an air injection crosshead type of engine. Air supply is furnished by a direct-connected three-stage air compressor.

attain this result, liquid fuel for use in an oil engine should be:

1. Of sufficient fluidity to enable pumping feasibly throughout the system without the necessity for preheating abnormally.

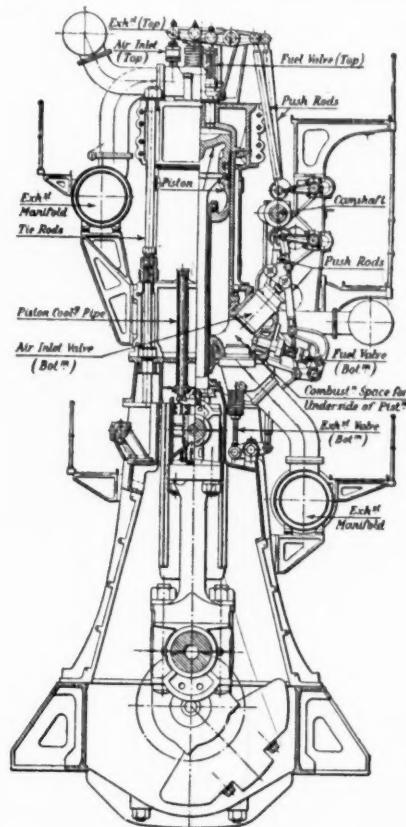
2. Free from bottom sediment or any other impurities which might clog the strainers, pump valves, fuel-injection valves, piping, nozzles or orifices according to the type of engine, or cause excessive cylinder wear.

3. As free as possible from water inasmuch as this latter will not only tend to interfere with ignition, but furthermore, it lowers the calorific value of the oil.

4. Of as low a sulphur content as possible, to avoid any chance formation of corrosive acids within the engine. Where fuel oils contain an abnormal percentage of sulphur, this latter may have an especially deleterious action on exhaust valves, corroding and causing leakage in many instances, depending, of course, upon the extent to which the metal corrodes, the pres-

ence of moisture and the chemical form in which sulphur exists in the oil. In this connection it is important to remember that the successful operation of any oil engine will largely depend upon the efficiency of the fuel pumps and the completeness of atomization of the oil. The two-cylinder engine, as a rule, can use a fuel oil with more sulphur in it due to the general absence of exhaust valves.

5. Refined to a sufficient extent to bring about the removal of highly volatile hydrocarbon fractions which, under the ordinary conditions of storage and handling might vaporize and render the fuel unduly hazardous due to the generation of inflammable mixtures with air.



Courtesy of Burmeister & Wain A/S

Fig. 4—Section through a double-acting four-stroke cycle Diesel engine. Each cylinder of this engine is capable of developing over 1100 shaft horse power at 125 R. P. M. An interesting feature is the oil-cooled piston and rod. The rod is fitted with a cast iron liner. Between this latter and the steel piston rod is a ring-shaped space through which the oil is carried to the piston. Oil is discharged through the middle of the bored out piston rod.

The Relation of Sulphur and Ash

To derive the maximum of power from a Diesel engine it is evident that every effort should be made to obtain a fuel oil as free as possible from ash, sulphur and other residual matter. In many cases, this will mean the re-

L U B R I C A T I O N

jection of heavier fuel oils or crudes. This will all depend on the design and construction of the engine. Some builders claim to have so perfected their method of combustion that even heavy Mexican or California crude oils can be satisfactorily burned. In general, however, the lower the proportion of residual matter or coke, upon distillation, the better will be the oil for Diesel engine purposes. A maximum of 5.0% is probably the usual upper limit for all oil engines.

Then as to the matter of ash, this component is detrimental owing to its abrasive nature and the excessive wear which it frequently causes on the cylinder walls, etc. Ash usually consists of mineral matter such as iron and aluminum oxides, quartz and other silicates, which being in finely pulverized condition become mixed and retained by the lubricating oil films.

Sulphur in turn has been discussed heretofore in regard to its potential corrosive tendencies when in contact with moisture. Fuel oils containing as high as 5.0% are claimed to be satisfactory by certain authorities, but where such are used, cast iron exhaust pipes should be installed, and every precaution taken to avoid presence of water vapor from chemical reactions, or otherwise, due to the resultant corrosive acids which would be formed. With high sulphur fuel oils entry of gases of combustion into the crankcase may also cause trouble from corrosion.

Fuels Classified

It will be of further interest to look into the types of fuels that are available today, and capable to a more or less extent, of meeting the above specifications.

It is the consensus of opinion that liquid fuels for Diesel engine service can be grouped in three definite classifications. Practically, these are based upon chemical characteristics; on the other hand the suitability of any particular product will include, as well, certain physical properties such as viscosity or relative fluidity, flash point, calorific value, etc.

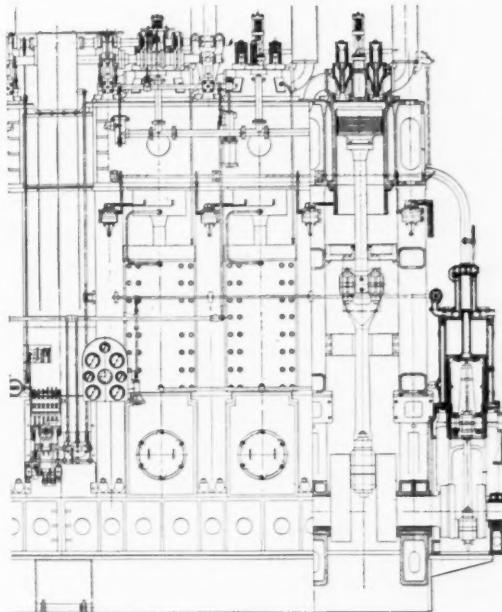
Petroleum Fuels

The first, and today, apparently the most adaptable group of products involve the petroleum or mineral oil series. A scientific definition would further explain them as being compounds of saturated and unsaturated hydrocarbons, containing a high percentage of hydrogen such as do paraffine and naphthenic oils.

We state these as being the most adaptable. Whether time will prove this statement, remains to be seen. From a practical viewpoint they are the most readily obtained today in most localities at prices commensurate with the price of coal. Therefore the oil engine is

designed to burn them in preference to other products which might give quite as good results, but are economically more or less out of the question.

In this same classification we can also group



Courtesy of Motorship and American Brown Boveri Electric Corp.
Fig. 5—Part sectional view of a six cylinder 2200 I. H. P. New York-Werkspoor Diesel engine of the four-cycle type. This engine is of the enclosed type, being forced lubricated throughout. Each cylinder is equipped with a force-feed lubricator.

the lignite, tar and shale oils which possess very much the same chemical characteristics. In the combustion of products of this first group, ignition in the present type of oil engine is more readily attained by reason of their comparatively high hydrogen and carbon contents and their volatility or ability to gasify at the operating temperatures involved.

Coal, Tar and Benzol Products

In the second group of available liquid fuels are generally included the products from bituminous coals such as coal tars, and those other products from which benzol is derived. In contrast with petroleum hydrocarbons it is interesting to note that coal tar products and benzols, as a whole, are not entirely suited to combustion in certain types of American Diesel engines, due to the difficulty with which they will ignite. For this reason they are often blended with petroleum products to lower their ignition temperature.

Furthermore, their cost, in comparison with petroleum oils is normally so far out of line, in many localities, that any attempt to adapt the oil engine to burn them would be economically inadvisable at this time. Certain European

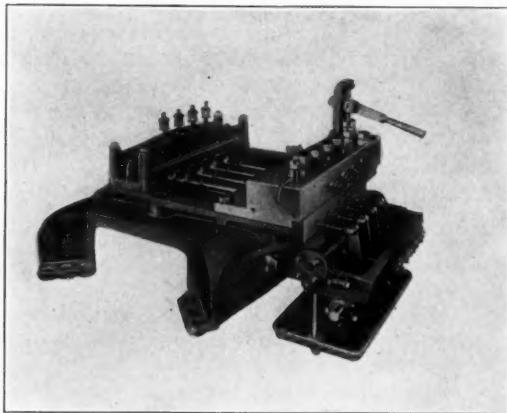
builders, however, have attempted this, it is understood with considerable success, especially where coal tars have been the fuel involved. Here, of course, comparative fuel costs may be assumed as being the essential reason for this attempted transition.

Vegetable Oils

The third group is composed of vegetable oils such as the products from the castor bean, the soya bean, cottonseed, peanut, etc. While a certain amount of experimentation has been carried out with a view to using these various oils as oil engine fuels, as yet but little advancement has been made. To be true, certain of them have been used to some extent with more or less success, and it is fair to presume that in the tropics where these oils would be more readily obtainable at fair prices, their usage will become quite practicable provided engines are suitably designed and adjusted, to conform to the usually higher ignition temperatures of these oils.

Whatever the grade of fuel involved, it must be borne in mind that the engine must be adapted to its characteristics, especially as to volatility. In other words, an engine designed or adjusted for one grade of fuel should preferably not be used with another without making adjustments as previously explained.

Probably the greatest problem in an engine unsuited to a grade of fuel oil is the occurrence of incomplete combustion, with its attendant possibility of piston rings becoming stuck, and cylinder lubrication and compression being



Courtesy of Bethlehem Shipbuilding Corp., Ltd.

Fig. 6—Fuel pump as used on the large unit type of single acting engine as shown in Fig. 3.

seriously affected. In general the extent to which complete combustion will be attained will depend upon the construction of the fuel valves and atomizers, the intimacy with which the mixing of fuel and air is brought about, and the construction of the cylinder heads or

combustion chambers. The heavier and less volatile the fuel, the higher should be the injection pressure to effect complete atomization and mixing with air.

LUBRICATION, LUBRICANTS AND THEIR APPLICATION

The fuel of course is essentially the factor which makes the Diesel engine run. The lubricants, on the other hand are the necessary means which must be used to keep it running. But just to keep running is not enough.

Unless an engine develops a maximum of power with a minimum of fuel consumption, a flagrant waste is occurring which must be corrected. Therefore, lubrication and its relation to the development of power requires careful attention.

Essential Characteristics

Regardless of whether a lubricant is to serve the engine cylinders or is to be used on the air compressor or bearings, certain basic characteristics are necessary, viz.:

1. It must be so carefully refined as to be able to withstand the usual stresses and strains of intensive service. Also it should be carefully fractionated or the lighter components so effectively removed that it will not be so volatile as to require an undue quantity to maintain a suitable lubricating film especially on the cylinder walls.
2. It should have as low an emulsification tendency as possible due to the contact with water which may occur. Filtration and very careful refinement will overcome this tendency.
3. It must be suited to the engine and also to the lubricating system installed; for we can readily appreciate that an oil might easily be an excellent lubricant, yet refined in such a manner as to be absolutely unsuitable for Diesel engine service.
4. Furthermore, it must be of such a viscosity or body as to maintain a lubricating film of suitable thickness between the wearing surfaces, under the prevailing temperatures of operation. Yet it should never be so heavy or viscous at these temperatures as to give rise to abnormal internal friction within itself, for this might readily develop excessive operating temperatures especially on the engine bearings.
5. It should be sufficiently adhesive to resist being squeezed out from between the wearing surfaces when subjected to the normal pressures of operation.
6. It should not congeal at any of the lower temperatures to which it might be sub-

L U B R I C A T I O N

jected during storage or operation. In this connection the pour test should be low enough to avoid the necessity for ever heating the storage tanks.

7. It should be capable of spreading readily over the wearing surfaces in the case of

ports involved, the gases being discharged in a straight line direction via the exhaust valves in the cylinder heads. Furthermore, in the four-cycle engine pressures on the moving parts is not always of the same intensity.

Of course it may be difficult to get the lubricating oil to spread uniformly over cylinder liner surfaces when the rings are under pressure. We must remember, however, that in the four-cycle engine the pressure on the rings is relieved during the second stroke. As a result the oil is readily spread over the cylinder liner, to materially facilitate the sliding action of the piston and rings during the subsequent strokes of the cycle.

Lubrication is important in that it must be positive and uniform, otherwise rings will be worn, or perhaps may become stuck, with an appreciable loss in compression.

The wrist-pin, for example, will also be affected. This part on certain engines will be subjected to relatively high temperatures with but little opportunity for radiation of its heat unless it is cooled mechanically.

Application of Cylinder Oils

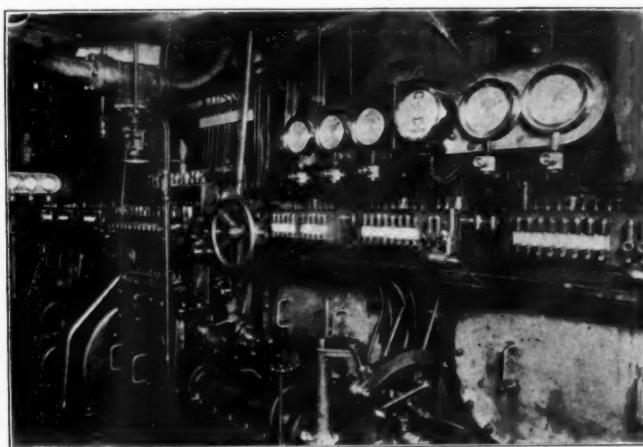
Quite as important as the grade of oil used for cylinder lubrication is the method and rate of application. The oil should be so fed as to impinge directly onto the pistons, the time and point of application being so planned that the charge will strike as nearly as possible between the first and second rings (from the top) when the piston is at the lowermost point of its stroke.

Successful Diesel engine cylinder lubrication is dependent upon four factors, i. e.:

- (a) The use of properly refined oil;
- (b) Application of sufficient though never excessive amounts;
- (c) Delivery through oil ways so located that the piston and rings will receive the maximum of this charge;
- (d) Application at exactly the right time.

Points of Delivery

The number of points at which the lubricant should be applied to the piston of a Diesel engine will depend naturally upon the type and size of the engine; two to four oil holes equidistantly located in the cylinder wall will generally suffice, although this will of course depend upon the bore of the cylinder. In the two-cycle engine care is taken that none of these



Courtesy of Worthington Pump & Machinery Corporation.

Fig. 7.—Operating platform of the engine shown in Figure 2, showing controls, &c., and the mechanical force-feed lubricators—one per cylinder, with leads to furnish oil to cylinders, air compressor and scavenging pump. Main bearings, crank-pin and other such parts are pressure-lubricated by an independent system located in the crank-case.

cylinder walls, not remaining in streaks or blotches for otherwise suitable sealing of the pistons might be impaired.

8. It must show as little carbon residue as possible, inasmuch as the decomposition which will occur when the oil is exposed to the intensive heat of combustion, will in the case of many oils develop a large amount of objectionable carbonaceous residuum. Furthermore, this latter should be capable of easy removal.

It is fully appreciated that for an oil to meet all the above requirements the most careful attention is necessary not only in refining, but also in transportation, storage and handling in the plant. The very best judgment is necessary in the selection of the ultimate oil, taking into account of course those requirements which in the particular case are most desired.

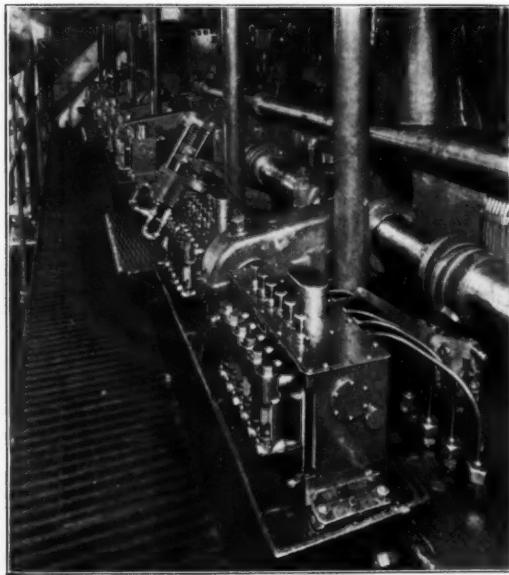
Cylinder Lubrication

Efficient lubrication of Diesel engine cylinders will be more or less influenced by the grade of the fuel and the completeness of combustion.

This is perhaps the most pertinent problem in the lubrication of the four-cycle engine cylinder. Unlike the two-cycle engine, there is not the heat developed during operation, nor is the lubricant on the cylinder walls subjected to the high velocity and vaporizing action of the exhaust gases, inasmuch as there are no exhaust

oil holes are located in line with the exhaust ports, for otherwise the exhaust gases would tend to carry off a certain amount of lubricant. This, of course, would be a direct waste.

One point of delivery is not considered as dependable due to the possibility of the op-



Courtesy of Motorship and Sun Shipbuilding and Dry Dock Company.

Fig. 8—Lubricator arrangement on a two-cycle opposed piston, solid-injection oil engine. Lubrication of the entire engine is by force feed. Mechanical lubricators serving the cylinders as shown, the crank-case parts being served by an independent pressure oiling system.

posite side of the cylinders being under-lubri- cated. In certain cases, this can be obviated somewhat by cutting an internal groove in the cylinder wall at the point or points of injection for more even distribution of the oil.

Importance of Piston Ring Fit

The effectiveness with which the lubricant will be distributed will also depend to a certain extent upon the fit of the piston rings. Loose rings will not only decrease this but also will allow blow-by to occur. The loss of compression and passage of hot gases which will result will naturally tend to cause overheating of the lower parts of the cylinder and piston, the oil film being either burned or dried up prematurely. Fortunately, however, there is not the same opportunity for dilution of the lubricating oil occurring as exists in the carburetor type of engine, due to the fact that the fuel charge is burned to practical completeness as fast as it enters the combustion chamber.

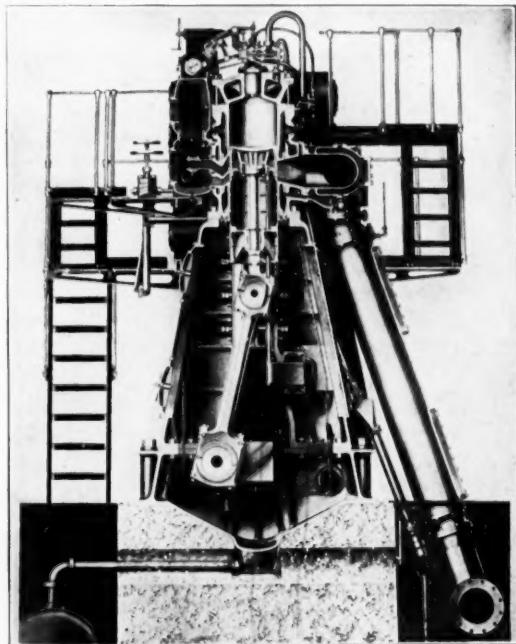
On the other hand where the rings are too tight a scraping action will be exerted over the cylinder walls, the lubricating film often being broken or at least dangerously reduced. To

counteract this possibility certain authorities advise slight beveling of the upper edges of the top piston rings in order to facilitate their sliding over the oil film on the up stroke.

Tight, improperly set rings may also lead to the seizure of pistons, especially where the lubricating film is not perfect, where an excessive amount of oil has been supplied or in case imperfect combustion is occurring. With certain grades of oil an excess of this latter will develop gummy residues due to their lack of free-burning characteristics. While the engine is hot, naturally these residues will be relatively pliable, though in all probability extremely viscous. On shutting down, however, they will often congeal to such an extent as to practically seal or freeze the piston to the cylinder, rendering subsequent starting a difficult proposition.

Incomplete Combustion and Carbonization

Imperfect combustion requires detailed consideration due to the extent to which it affects



Courtesy of Busch-Sulzer Brothers Diesel Engine Co.
Fig. 9—A vertical two-cycle stationary Diesel engine, showing details of cylinder, valve, connecting rod, bearing construction, etc. Pressure lubrication and filtration after each circulation insures a continuous supply of clean, cool oil at all times.

fuel economy. In general the former is the result of low compression pressures caused either mechanically or by leaky rings, excessive overloads or insufficient air, (in other words the firing of too rich a mixture as we would say in automobile parlance).

L U B R I C A T I O N

Where incomplete combustion is allowed to continue carbonization will practically always occur especially on the piston head and in all probability around the rings. Therefore, carbonization is often the parent of faulty valve action and stuck piston rings. In turn this latter occurrence will cause compression losses.

In consequence a complete cycle of inefficiency may result. Where rings are stuck in their grooves they must, therefore, be loosened as soon as possible. Oftentimes kerosene or a lye-water mixture will serve this purpose, cutting the gummy matter effectively, in case merely scraping away the deposits is not sufficient.

Means of Lubrication

To bring about cylinder lubrication most effectively the oil should be delivered regularly to the cylinder and piston by some form of positive lubricator, which will insure a charge of sufficient volume to cover the entire cylinder wall under the swabbing action of the piston.

Force feed lubrication is perhaps the most effective means of delivering oil to the cylinder of a Diesel engine. Practically speaking force feed lubrication, as used for cylinders and air compressors, can be regarded as high pressure lubrication, as compared with the relatively low pressure systems used for the miscellaneous bearings of certain types of engines. Essentially, Diesel engine lubrication must be positive, and capable of functioning under sufficiently high pressures to withstand the opposing operating pressures. In the air compressor of a full Diesel engine, for example, these would be very high, even though the oil may be delivered at a time when the pressure exerted on the piston is lowest.

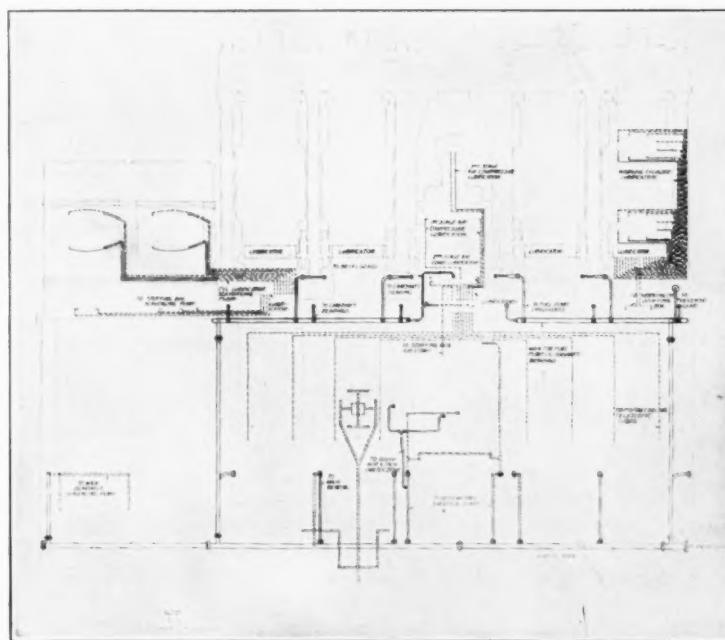
Amount of Cylinder Oil Required

It will also be of interest to deal with the amount of oil which should be used to lubricate cylinders. Usually such factors as the grade and quality of the oil, the method of application, the number of oil feeds and the type and construction of the engine must be considered.

In general, while certain figures (such as say,

10 to 20 drops per minute) could be quoted based on ideal operating conditions, it is safe to state that a certain amount of experimentation must always be carried out, for practically every oil will vary in its lubricating ability dependent upon its viscosity and manner of refinement.

The more even the distribution of the oil, of course, the greater economy of consumption will result. In many instances the four-cycle engine will require less cylinder lubricant than the two-cycle, for the reason that cylinder wall temperatures are not usually as high. Conservative estimates figure about 4,000 horsepower hours per gallon for the former, as compared with approximately 1,000 for the latter, although these will of course vary with the manner in which the engine is operated, the type of lubricating system employed, and the nature and volatility of the oil. Suffice it to say that cylinder oil economy is most important not only from the viewpoint of cost, but also due to the fact that possible gumming and carbonizing of the piston rings, blow-by, carbon



Courtesy of New London Ship & Engine Company.
Fig. 10—Phantom side view of a four cylinder, two-cycle double acting, air injection Diesel engine, showing lubricating system in detail. All piping, lubricators and other oiling equipment are clearly brought out in such a manner as to be especially enlightening and instructive.

deposits on the piston head and compression losses will be prevented.

Where a mechanical force feed lubricator is used capable of feeding oil in synchronism with the strokes of the pistons, frequently it is possible to control the oil feed so accurately

as to approximate the theoretical requirements of the engine for the particular oil in service.

Where engines are of the enclosed crankcase splash-oiled type, additional cylinder lubrication if necessary is often carried out separately. A certain amount of lubrication will be derived from the vaporous fog of lubricant which is present in the crankcase during operation. Naturally this should justify a certain amount of reduction in oil feed to the cylinders themselves. The extent to which secondary cylinder lubrication of this nature is brought about, however, is not measurable with any accuracy; therefore the amount to which cylinder lubrication could be reduced cannot be definitely stated.

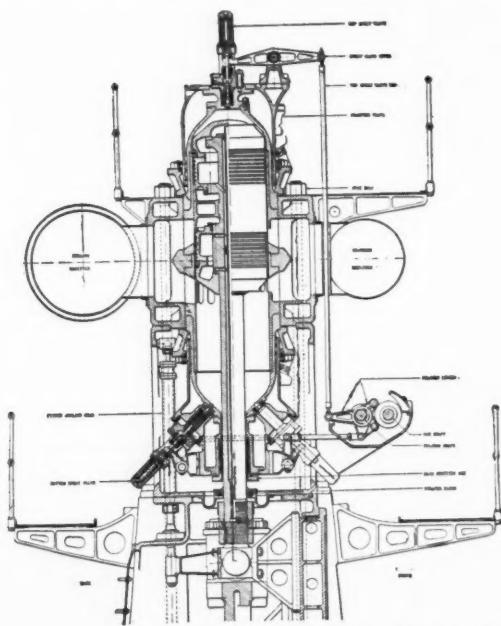
Bearing Lubrication

Other pertinent wearing parts of the Diesel engine which require careful lubrication are the wrist pins, the crank pins, main bearings and crosshead guides. With the possible exception of the wrist pins which are contained in an enclosed position and may be subjected

mechanical lubricator, or the principles of splash lubrication (in the enclosed crankcase engine) are all readily adaptable.

On large engines the first is preferred by many authorities. In effect it is probably the most dependable system in that it furnishes a continuous stream of oil to all the bearing parts in question and is capable of being put in series with a filtration or purification system which will insure the delivery of practically pure oil, thus eliminating the possibility of clogged oil ways. Furthermore, the oil feed to each part, in certain cases, can be independently controlled.

With the mechanical lubricator it is possible to make it serve both cylinder and bearing lubrication, by keeping the requisite lubricants in separate compartments, although where but one grade of oil is required this would not be necessary. With more than one oil there is, however, always a possibility of these being mixed up and for this reason many authorities insist that separate lubricators be used under such conditions.



Courtesy of Worthington Pump and Machinery Corp.

Fig. 11—Transverse section through cylinder of the two-cycle double acting Diesel engine shown of Fig. 2. Essential constructional features are clearly indicated.

to considerable unradiated heat, the above parts will in general involve no difficult lubricating problems.

Pressures are usually high, clearances low and operating speeds frequently high; yet the circulating force feed oiling system, the me-

AIR COMPRESSOR LUBRICATION

Lubrication of the Diesel engine air compressor is so important as to require individual consideration. In fact, in the air injection type of engine, the air compressor can probably be regarded as the heart of the system by virtue of the part it plays in bringing about combustion.

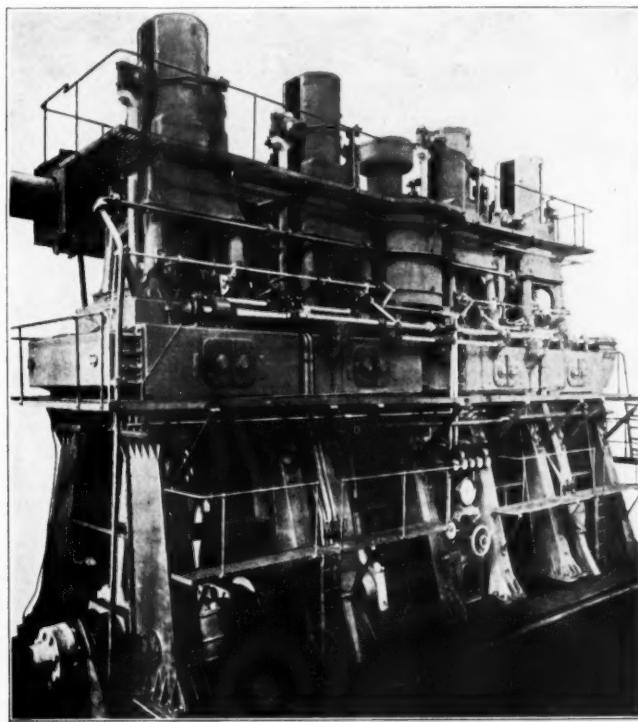
To serve this purpose, however, it is absolutely necessary that the compressor be properly lubricated. By this we mean that it should be served with just the right amount of the most suitable grade of oil. Therefore, lubrication may be regarded as one of the secrets of successful compressor operation.

The air compressor as usually installed in higher powered Diesel engines will generally have either three or four stages, and will be equipped with suitable intercoolers. The compression of air to pressures in the neighborhood of 1,000 pounds will of course develop a considerable amount of heat; it is the function of the intercoolers to reduce this heat and thereby keep cylinder temperatures down to minimize the extent of oil vaporization. This is of course in the interests of safety, for otherwise accumulations of dust and carbonaceous matter in the intercoolers, etc., might easily so restrict the air passages as to increase the velocity and consequently the frictional temperature of the air to a dangerous extent.

LUBRICATION

Deposits of Dirt and Carbon

While dirty air is perhaps one of the most general causes of such accumulations of foreign



Courtesy of Sun Shipbuilding and Dry Dock Co.

Fig. 12—Side view of an opposed-piston type, two-cycle oil engine. This engine is distinctive for the absence of valves; its direct reversibility, and the equalization of stresses and strains of operation.

matter, we must not forget that an excessive amount of lubricating oil will tend to develop carbonaceous matter which will materially enhance the accumulation of deposits.

In addition an excess of oil fed to the compressor cylinders may bring about leaky valves due to a certain amount of the oil becoming carbonized on the latter. All this, of course, leads to a decrease in operating efficiency. For this carbonaceous matter being relatively sticky in the early stages of its formation, will also tend to adhere to the piston rings, thereby causing them to become inoperative; furthermore, it will tend to destroy the lubricating film and result in scored cylinders.

Unfortunately there is no oil which will not deposit some carbon; on the other hand, there

is a surprising difference in the nature and quantity of this carbon which will be developed by different oils.

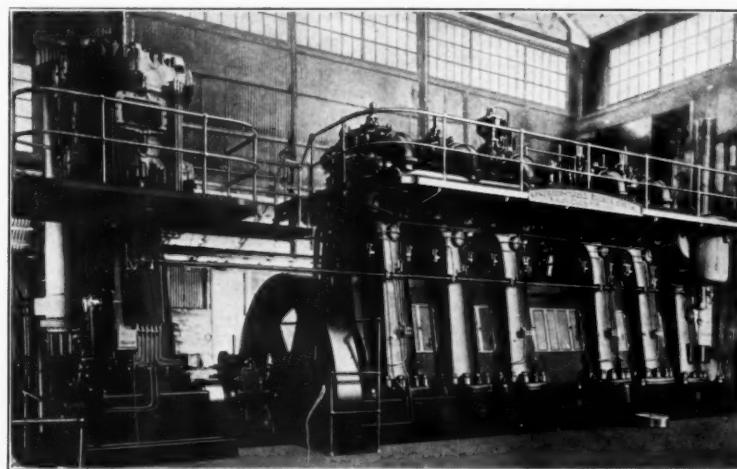
Consequently, not only must an oil be most carefully selected, but also, whatever its characteristics, the utmost care should be taken to prevent the use of more oil than is necessary.

In this respect it is very difficult for some operators to realize that but one or two drops of oil per minute is all that is necessary. This is effectively counteracted in many Diesel air compressors by so designing that the intermediate stage is at the bottom. As a result of such construction there is always a pressure opposing the tendency of the oil to work up into the air space from the lowest cylinder wall where it is thrown by the crankpin.

Air Cylinder Lubrication

To best effect air compressor cylinder lubrication, each cylinder should be equipped for force feed or pressure lubrication, whereby uniform and measured quantities of oil can be fed regularly. As has been stated, only a drop or two a minute to the first one or two stages will be necessary.

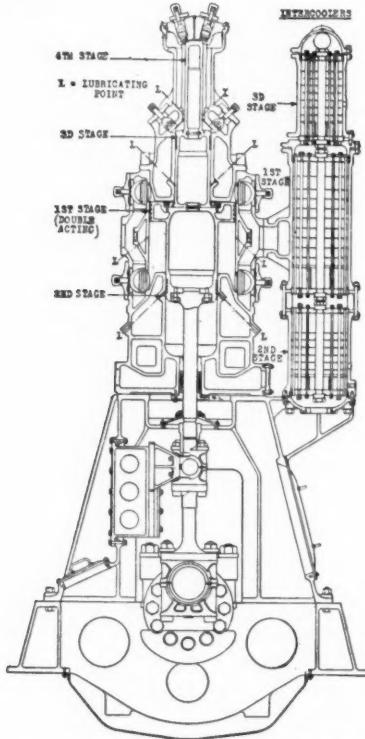
The third or last stage will usually be abundantly served with oil carried up from the preceding. On the other hand, no hard and fast rule can be laid down in this



Courtesy of Nordberg Mfg. Co.
Fig. 13—A two-cycle Diesel engine driving an air compressor. Lubricating oil piping and connections are clearly shown.

regard, and the safest course to follow in determining upon the quantity of oil to use is to

remove the valves at periodic intervals and examine the cylinder walls. A properly lubricated wall should be coated with a film of oil which will just barely dampen or stain a cigarette paper.



Courtesy of Worthington Pump & Machinery Corp'

Fig. 14—Sectional view of the air compressor installed on the engine shown in Figure 2. Note in particular, the points of cylinder lubrication indicated by "L" in each case.

Overheating and Flash Point

This matter of the heat due to compression has caused an unfortunate confusion in the minds of some operators as to the interpretation of the flash points of lubricating oils for air compressors.

Flash point readings are of value only in in-

dicating the relative initial volatility of different oils, and are not definite temperatures at which they "boil" or go completely into vapor corresponding to the boiling point of water.

Oils of the proper consistency which leave unusually low carbon are much to be preferred to oils of high flash point. Certain engineers, however, in their eagerness to secure oils of high flash point will frequently overlook this matter of subsequent carbon deposits. This is, of course erroneous.

The occasional cases of air compressor explosions which have been investigated carefully, suggested that the cause was *excessive carbon deposits* in the piping, which had greatly restricted the area of the passages. The real cause of these explosions is still to be explained satisfactorily, but it is significant that practically all occurred in piping remote from the compressor, and hence at places not subjected to the highest temperatures.

Oil made from inferior stocks is therefore, inadvisable, for compressor lubrication, even though it may be cheaper; the probability of very high carbon residues is too great.

It is very desirable to clean out the air compressor system at intervals, and wash out the carbon deposits before they grow to large proportions. Kerosene or any similar light oil must under no circumstances be used for this purpose, because of the danger of explosive mixtures due to their high volatility, and the comparatively large quantity used.

Some operators look with favor on the use of soap suds for cleaning, the solution of soft soap and water being fed into the air intake or through the lubricator about ten times as fast as the usual oil supply. The quantity used must be judged by the amount of carbon found on the valves when they are inspected. After such an application all receivers must be blown down to remove all the soapy water, and oil used again for a time before shutting down, in order to prevent rusting.